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(54) METHOD AND APPARATUS FOR APPLYING LIQUID COMPOSITIONS IN RAIL SYSTEMS

VERFAHREN UND VORRICHTUNG ZUM AUFBRINGEN VON
FLÜSSIGKEITSZUSAMMENSETZUNGEN AUF SCHIENENSYSTEME

PROCEDE ET APPAREIL PERMETTANT D'APPLIQUER DES COMPOSITIONS LIQUIDES DANS
DES SYSTEMES FERROVIAIRES

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CA-A1- 2 003 523 **US-A- 5 477 941**
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Description**FIELD OF INVENTION**

[0001] The present invention relates to liquid composition application systems used in rail systems.

BACKGROUND OF THE INVENTION

[0002] The control of friction and wear of metal mechanical components that are in sliding or rolling-sliding contact is of great importance in the design and operation of many machines and mechanical systems. For example, many steel-rail and steel-wheel transportation systems including freight, passenger and mass transit systems suffer from the emission of high noise levels and extensive wear of mechanical components such as wheels, rails and other rail components. The origin of such noise emission, and the wear of mechanical components may be directly attributed to a number of factors: wheel and rail interaction characteristics; operating conditions including curvature, speed; and rail material strength including hardness.

[0003] Mechanical friction at the wheel-rail interaction includes: a) friction on both tangent and curved tracks due to rolling friction on the horizontal interface between wheel and rail and b) curve resistance is the additional resistance in curves due to increased lateral friction forces in curves. The sum of the two effects usually accounts for about 5 to 10% of a train's energy consumption in passenger trains and up to 30% very heavy freight trains.

[0004] In a dynamic system wherein a wheel rolls on a rail, there is a constantly moving zone of contact. For purposes of discussion and analysis, it is convenient to treat the zone of contact as stationary while the rail and wheel move through the zone of contact. When the wheel moves through the zone of contact in exactly the same direction as the rail, the wheel is in an optimum state of rolling contact over the rail. However, because the wheel and the rail are profiled, often misaligned and subject to motions other than strict rolling, the respective velocities at which the wheel and the rail move through the zone of contact are not always the same on a tangent section of the railway, causing sliding movement between the wheel and the rail. The sliding movement is more pronounced when fixed-axle railcars negotiate curves wherein true rolling contact can only be maintained on both rails if the inner and the outer wheels rotate at different peripheral speeds. This is not possible on fixed-axle railcars. Thus, under such conditions, the wheels undergo a combined rolling and sliding movement relative to the rails. Sliding movement may also arise when traction is lost on inclines thereby causing the driving wheels to slip. In addition, when the when railcars pass through a curvature, the centripetal force will cause additional friction between the flanges of the profiled railcar wheel and the inside side of the 'high rail' of the curvature.

[0005] Hence, the requirement for reduction in sliding

movement between the railcar wheels and the rail is different between tangent sections and curvature of a railway, between incline and decline of a railway, and a combination thereof.

- 5 **[0006]** The magnitude of the sliding movement is roughly dependent on the difference, expressed as a percentage, between the rail and wheel velocities at the point of contact. This percentage difference is termed creepage.
- 10 **[0007]** At creepage levels larger than about 1%, appreciable frictional forces are generated due to sliding, and these frictional forces result in noise and wear of components (H. Harrison, T. McCanney and J. Cotter (2000), Recent Developments in COF Measurements at the Rail/Wheel Interface, Proceedings The 5th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems CM 2000 (SEIKEN Symposium No. 27), pp. 30-34). The noise emission is a result of a negative friction characteristic that is present between the wheel and the rail system. A negative friction characteristic is one wherein friction between the wheel and rail generally decreases as the creepage of the system increases in the region where the creep curve is saturated. Theoretically, noise and wear levels on wheel-rail systems may be reduced or eliminated by making the mechanical system very rigid, reducing the frictional forces between moving components to very low levels or by changing the friction characteristic from a negative to a positive one, that is by increasing friction between the rail and wheel in the region where the creep curve is saturated. Unfortunately, it is often impossible to impart greater rigidity to a mechanical system, such as in the case of a wheel and rail systems used by most trains. Alternatively, reducing the frictional forces between the wheel and the rail may greatly hamper adhesion and braking and is not always suitable for rail applications. In many situations, imparting a positive frictional characteristic between the wheel and rail is effective in reducing noise levels and wear of components.
- 25 **[0008]** In recent years, significant advancements in lubricant technology have led to the production of special rail lubricants containing friction modifiers that produce "positive friction characteristics" wherein the coefficient of friction increases with the speed of sliding. For example, US 6,136,757 describes friction modifiers with high or very high positive coefficients of friction; US 2004 0 038 831 A1 describes a high positive friction control composition with a rheological control agent, a lubricant, a friction modifier, and one, or more than one of a retentivity agent, an antioxidant, a consistency modifier, and a freezing point depressant; and WO 02/26919 (US 2003 0 195 123 A1) describes a liquid friction control composition with enhanced retentivity with an antioxidant. The liquid friction control composition may also comprise other components such as a retentivity agent, a rheological control agent, a friction modifier, a lubricant, a wetting agent, a consistency modifier, and a preservative. These friction modifiers are typically solid powders or fine par-

ticulates that are suspended in relatively thick fluids. These solid materials enhance friction between a wheel and the rail to promote rolling engagement rather than sliding.

[0009] With the development of these new compositions, there is a need for lubricant delivery systems that can accurately and precisely apply such lubricants to the rail. Prior art devices for application of the lubricant or friction modifiers can be classified into two categories: stationary devices on the wayside; and devices mounted on a vehicle.

[0010] Stationary devices are usually deployed immediately preceding a location where application is required, the movement of the train tends to move the liquid composition into the area so as to modify the friction on the rail sections and wheel flanges as the train passes. There have been several designs of stationary devices, and apparatus for securing them so as to permit the automatic application of an appropriate composition to the rail when a train passes. In some of these devices, it is the depression of the roadbed that triggers the dispensation of a composition; in others, it is the tripping of a mechanical device, such as a lever or a plunger, by the train's wheels that activates a composition dispensing mechanism. Example of such prior art devices is shown in U.S. 5,641,037. These prior art devices are often mechanically complex and difficult to install and maintain in the field.

[0011] Mobile liquid composition delivery devices for lubricating rails, such as the one described in US 5,992,568, may be mounted on a track vehicle, such as a pickup truck (Hi Rail system) equipped with additional flanged wheels.

[0012] US 6,578,669 describes a liquid delivery system mounted on a railroad locomotive for applying to a composition to a rail. The system comprises a lubricant path, a reservoir for holding the lubricant, a pump to convey the lubricant along the lubricant path, and a dispensing nozzle mounted to the locomotive above each rail for directing the lubricant onto each rail. However, as drive wheels require good contact with the rail surface, slippage will occur if lubricant is applied in front of any of the drive wheels, and this must be avoided. As locomotives can move in both directions, the delivery system mounted on a locomotive can only be used in an orientation where the active nozzle is behind the driving wheels of the locomotive and this contributes to the complexity of the mechanical systems that already exist on a locomotive. When several locomotives are used in series for pulling heavy freight trains, the nozzle needs to be located behind all driving wheels of the locomotives. The addition or removal of locomotives during use increases the complexity of determining the location of the delivery system within a locomotive consist. Furthermore, a locomotive has limited space for accommodating a liquid reservoir, pump, and delivery systems for applying a liquid composition to a rail system.

[0013] Application of liquid compositions within a rail system maybe location dependent, so that a certain liquid

compositions may be applied at a certain location of the rail system, applied in different amount at different locations of rail, or different combinations of friction modifiers or friction modifiers and lubricants may be used at different locations of the rail, for example, applied to the top of the rail, or along a side surface of the head of the rail.

[0014] WO 01/18558 discloses methods and apparatus for measuring navigation parameters of a locomotive. The method includes the steps of phase locking a pair of GPS receivers having antennas at different locations on a locomotive to reference signals received from a set of at least three satellites, determining a set of phase differences between the reference signals received at the antennas, and determining at least one of an accurate heading, and/or heading rate of the locomotive using the set of phase differences between the reference signals.

[0015] US 5,477,941 is directed to a method and apparatus for optimizing on-board rail lubrication for both curved and tangent tracks. The amounts of two lubricants applied are controlled by a microprocessor and operational parameters including speed, trailing tons, degree of rail curve, temperature, rain, braking and train direction. A displacement sensor mounted on the truck measures the degree of curve and the method also utilizes the output of the locomotive computer provided to the train operations recorder for speed, trailing tons, brake application, emergency braking and direction of travel.

[0016] CA 2,003,523 relates to a method and apparatus for optimizing on-board rail lubrication for both curved and tangent tracks. The amounts of two lubricants applied are controlled by a microprocessor and operational parameters including train size, angle of attack of the wheels on the rail, train speed, temperature, humidity and rheological characteristics of the lubricants being used. The system measures the degree of curve of the track and/or the angle of attack a truck wheel would make with the rails and is based on an initial calibration for each different make locomotive on which it is installed.

[0017] Global position system (GPS) has been widely used for locating position on earth. It is well known in the art that navigation systems have been developed, for roadway type vehicles which use a GPS system for determining the approximate location of the vehicle in relation to a street database. By relating the approximate location of the vehicle with information concerning its direction of travel, it is sometimes possible to locate the vehicle on the database

SUMMARY OF THE INVENTION

[0018] The present invention relates to liquid composition application systems used in rail systems.

[0019] It is an object of the invention to provide a novel method and apparatus for applying liquid compositions in rail systems.

[0020] This object is achieved by the device of claim 1 and the method of claim 15. Preferred embodiments are defined by claims 2-14 and 16-19.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] These and other features of the invention will become more apparent from the following description in which reference is made to the appended drawings wherein:

[0022] FIGURE 1 shows a prior art liquid composition application system;

[0023] FIGURE 2 shows a side view of an example of a liquid composition application system mounted in a rail car according to an aspect of the present invention;

[0024] FIGURE 3 shows a top view of an example of a liquid composition application system as illustrated in Figure 2;

[0025] FIGURE 4 shows a side view of an example of a liquid composition application system as illustrated in Figure 2 (viewed from the end of the rail car);

[0026] FIGURE 5 shows a end view of an example of circulation equipment (160) mounted on the side of the reservoir (120) as illustrated in Figure 4 (viewed from the side of the rail car);

[0027] FIGURE 6 shows a end view of an example of main electrical equipment (150) and circulation equipment (160), mounted on the side of the reservoir as illustrated in Figure 4 (viewed from the side of the rail car);

[0028] FIGURE 7 shows an end view of an example of a reservoir of the liquid composition application system as illustrated in Figure 4 (viewed from the side of the rail car);

[0029] FIGURE 8 shows a cross sectional view of an example of a reservoir as illustrated in Figure 4;

[0030] FIGURE 9 shows a side view of a rail wheel assembly showing an example of a way of attaching a nozzle assembly to the side frame (140);

[0031] FIGURE 10 shows a front view of a rail wheel assembly illustrated in Figure 9;

[0032] FIGURE 11 shows a top view of a rail wheel assembly illustrated in Figure 9;

[0033] FIGURE 12 shows a schematic of a train consist passing through a rail with a curvature;

[0034] FIGURE 13 shows a block diagram of an example of a control system for applying a liquid composition

[0035] FIGURE 14 shows tank level data indicating utilization of liquid composition by a rail car fitted with a liquid composition application system as described herein.

DETAILED DESCRIPTION

[0036] The present invention relates to liquid composition application systems used in rail systems.

[0037] The following description is of a preferred embodiment.

[0038] In railway industry, especially for the transport of freights, one or more locomotives can be physically connected together, with one locomotive designated as a lead locomotive and the others as trailing locomotives,

this is usually called a 'locomotive consist'. A 'train' or a 'train consist' means a combination of revenue generating cars (RGC; also called rail cars), and a locomotive consist. A rail car can be a passenger car or a freight car for example, but not limited to, a flat bed car, a refrigerated car, a bulk materials car for example an ore car, a chemical car, a seed or agricultural materials car, or a box car. Freight cars may unload by tipping. A common characteristic of a rail car is that it is not self-propelled. In contrast, a locomotive, or a mobile liquid composition delivery device such as the one described in US 5,992,568 (a Hi Rail system), are self-propelled.

[0039] Figure 1 shows a prior art composition delivery system (US 6,578,669) mounted on a railroad locomotive for applying a liquid composition to a rail. A single locomotive (10) is attached to rail car (12). A delivery system (20), mounted in locomotive (10) comprises a metering and a dispensing system (60), comprised of individual dispensing assemblies (60C and 60D), a tank (32) for

10 storing a liquid composition, and a delivery path (44) to convey the composition from the tank (32) to the nozzles (34 and 82). Piping system (44) includes a section that extends into the tank (32), and a pump (38) that is operatively disposed within piping section (44). A dispensing

15 conduit extends from housing (62) to a dispensing nozzle (82). Operative components for metering and dispensing the composition are disposed within a watertight housing (62).

[0040] The present invention provides a method for

20 applying a liquid composition to a rail surface comprising, supplying the liquid composition in one or more than one reservoir on a rail car (revenue generating car), and applying the liquid composition from the one or more than one reservoir to the rail surface. The liquid composition

25 may be applied to any section of rail, for example, a curved section of rail, a tangent (straight) section of rail, or both a curved and tangent section of rail. Furthermore, the supply, and the regulation of the supply of the liquid composition may be self-contained within the rail car. In

30 this manner there is no need to have the rail car in communication with the locomotive for the liquid composition to be applied to the rail surface. Rather, the supply, and regulation of the supply, of the liquid composition of the rail car may operate independently from the locomotive.

35 By having the liquid reservoir and control of the reservoir self-contained within the rail car, the rail car may be used within any train consist without requiring additional wiring to the locomotive. This ensures ease of adapting the revenue generating car comprising the liquid composition

40 and reservoir, to any train system.

[0041] With reference to Figures 2-11, there is shown an example of a liquid composition delivery system (100)

45 as part of a rail car (110). The example shown in Figure 2, which is not to be considered limiting, is that of an ore car. The delivery system has a liquid composition reservoir (120) for storing a liquid composition that is to be applied to the rail. This reservoir may comprise one or

50 more than one compartment, depending upon whether

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By having the liquid reservoir and control of the reservoir self-contained within the rail car, the rail car may be used within any train consist without requiring additional wiring to the locomotive. This ensures ease of adapting the revenue generating car comprising the liquid composition

and reservoir, to any train system.

[0042] FIGURE 15 shows a side view of an example of a liquid composition application system mounted in a rail car according to an aspect of the present invention;

[0043] FIGURE 16 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0044] FIGURE 17 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0045] FIGURE 18 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0046] FIGURE 19 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0047] FIGURE 20 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0048] FIGURE 21 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0049] FIGURE 22 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0050] FIGURE 23 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0051] FIGURE 24 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0052] FIGURE 25 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0053] FIGURE 26 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0054] FIGURE 27 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0055] FIGURE 28 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0056] FIGURE 29 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0057] FIGURE 30 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0058] FIGURE 31 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0059] FIGURE 32 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0060] FIGURE 33 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0061] FIGURE 34 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0062] FIGURE 35 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0063] FIGURE 36 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0064] FIGURE 37 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0065] FIGURE 38 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0066] FIGURE 39 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0067] FIGURE 40 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0068] FIGURE 41 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0069] FIGURE 42 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0070] FIGURE 43 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0071] FIGURE 44 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0072] FIGURE 45 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0073] FIGURE 46 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0074] FIGURE 47 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0075] FIGURE 48 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0076] FIGURE 49 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0077] FIGURE 50 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0078] FIGURE 51 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0079] FIGURE 52 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0080] FIGURE 53 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0081] FIGURE 54 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0082] FIGURE 55 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0083] FIGURE 56 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0084] FIGURE 57 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0085] FIGURE 58 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0086] FIGURE 59 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0087] FIGURE 60 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0088] FIGURE 61 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0089] FIGURE 62 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0090] FIGURE 63 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0091] FIGURE 64 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0092] FIGURE 65 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0093] FIGURE 66 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0094] FIGURE 67 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0095] FIGURE 68 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0096] FIGURE 69 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0097] FIGURE 70 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0098] FIGURE 71 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0099] FIGURE 72 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0100] FIGURE 73 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0101] FIGURE 74 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0102] FIGURE 75 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0103] FIGURE 76 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0104] FIGURE 77 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0105] FIGURE 78 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0106] FIGURE 79 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0107] FIGURE 80 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0108] FIGURE 81 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0109] FIGURE 82 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0110] FIGURE 83 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0111] FIGURE 84 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0112] FIGURE 85 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0113] FIGURE 86 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0114] FIGURE 87 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0115] FIGURE 88 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0116] FIGURE 89 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0117] FIGURE 90 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0118] FIGURE 91 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0119] FIGURE 92 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0120] FIGURE 93 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0121] FIGURE 94 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0122] FIGURE 95 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0123] FIGURE 96 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0124] FIGURE 97 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0125] FIGURE 98 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0126] FIGURE 99 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0127] FIGURE 100 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0128] FIGURE 101 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0129] FIGURE 102 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0130] FIGURE 103 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0131] FIGURE 104 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0132] FIGURE 105 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0133] FIGURE 106 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0134] FIGURE 107 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0135] FIGURE 108 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0136] FIGURE 109 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0137] FIGURE 110 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0138] FIGURE 111 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0139] FIGURE 112 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0140] FIGURE 113 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0141] FIGURE 114 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0142] FIGURE 115 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0143] FIGURE 116 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0144] FIGURE 117 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0145] FIGURE 118 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0146] FIGURE 119 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0147] FIGURE 120 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0148] FIGURE 121 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0149] FIGURE 122 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0150] FIGURE 123 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0151] FIGURE 124 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0152] FIGURE 125 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0153] FIGURE 126 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0154] FIGURE 127 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0155] FIGURE 128 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[0156] FIGURE 129 shows a side view of an example of a liquid composition application system as illustrated in Figure 15 (viewed from the end of the rail car);

[0157] FIGURE 130 shows a top view of an example of a liquid composition application system as illustrated in Figure 15;

[01

one or more than one liquid composition is to be applied to the rail. One or more than one nozzle assembly (220, see Figures 9-11) may be attached to the rail car for example at a side frame (140) between the railcar wheels (130; Figures 9-11). It is preferred that at least two nozzle assemblies are mounted on a rail car, one assembly on each side of the rail car in order to deliver the composition to one track, or both tracks of the rail system. Each nozzle assembly may comprise one or more than one nozzle, depending upon whether the top of the rail, the side of the head of the rail (gauge face), or both are to be treated with a composition.

[0042] The delivery system (100) may comprise a plurality of metering and a dispensing systems (160, Figures 3 and 6), for example one or two metering and a dispensing systems, a circulation pump (164, Figure 4) to mix, circulate and refresh the composition through the lines of a pipe system (163) that extend from the reservoir to the metering and dispensing system. The circulation pump (164) may also maintain pressure with the pipe system (163), which is typically a closed loop pipe system, made from any suitable material for example but not limited to a polymeric material, stainless steel, or the like. The circulation pump (164) also conveys the liquid composition from the reservoir (120), through a filter (168), to a supply line (158) entering one or both of the metering and dispensing systems (160). The circulation pump may be fitted with differential pressure switches that can shut off the pump in the event that the filter becomes clogged. Delivery of the composition from the pipe system (163) to the supply line (158) may be regulated by one or more than one valve, for example a solenoid valve. Each dispensing system may include a metering pump (located within dispensing system 150) that delivers the liquid composition received from the pipe system (163), via a supply line (e.g. 158), to one or more than one nozzle assembly (220; Figures 9-11) via a delivery path (e.g. 166; Figures 5, 6 and 9). The dispensing system (160) may also be fitted with solenoid valves and pressure switches to open, close, and regulate the flow of the composition. One metering and dispensing system (160) may be used to supply both of the nozzles on either sides of the rail car (110), or two dispensing systems (160) may be used as shown in Figures 5 and 6, each one independently supplying liquid composition to the nozzle assembly (220).

[0043] Electrical components involved in regulating and monitoring delivery of the liquid composition are placed within a protected housing (150), for example at one end of the reservoir (120). The electrical components may include but are not limited to one or more than one microprocessor, programmable logic controller, or computer, that receive information about the rail system during train consist travel, in order to regulate liquid composition delivery to the rail system. Preferably, there is an operator-actuated interface, for example a touch screen, or a radio frequency transceiver that permits remote access to the data and information gathered from the rail

car, and that permits implementing operating criteria as required. The electrical components of the control system may carry out, but are not limited to the following determinations:

- 5 - processing changes in topological information in the rail system, for example using a GPS or other rail topological sensing systems as described herein;
- 10 - controlling the dispensing system as required using information obtained from evaluation of rail topographical data, for example but not limited to, orientation of the rail car, speed of the rail car, curve sensing, severity of curve, changes in elevation, or temperature, to regulate composition delivery to one or both of the tracks, to the top or gauge-face of the rail, or both;
- 15 - monitoring pressure, temperature, valve status, pump status and other circulation parameters within the reservoir, pipe system, supply lines, circulation pump, metering pump(s), filter(s), and nozzle assemblies;
- 20 - controlling the heating system as required within the reservoir, pipe system, supply lines, circulation pump, metering pump(s), filter(s), and nozzle assemblies;
- 25 - regulating the metering pump output with respect to rail car speed, to ensure a consistent amount of the fluid composition is applied to the railhead;
- 30 - monitoring tank level and controlling dispensation of the fluid composition. For example if a low tank level switch is activated, shuts down fluid dispensation if high pressure is detected in the dispensing system, switches off the fluid dispensation if a specific drop in brake pipe pressure is determined, or if atomizing air pressure is lost. Furthermore, monitoring tank levels provides an indicator that the fluid composition is being applied to the rail surface;
- 35 - shutting off the delivery system below a threshold rail car speed, for example below about 5 to about 10 mph, or more preferably, below about 7 mph;
- 40 - determining the orientation of the rail car within respect to the train consist. This ensures that the liquid composition is delivered to the nozzle assembly on the desired side of the rail car, for example when applying to curved track; and
- 45 - a combination of the above.

[0044] Orientation of the rail car (110) within a train consist may be required if rail cars are rotated within the train consist, for example to equalize wheel wear. Rail

car orientation may be determined using any system that can determine if one (e.g. the A) or the other end (B) of the rail car is facing forward within the train consist. Non limiting examples for determining orientation of a rail car include the use of infrared, laser or other light beams and corresponding sensors to determine beam reflection or interruption and using this signal to interpret which end of the rail car, A or B, is facing forward, or the use of electrical circuit monitoring devices, so that when the rail is linked to a power source of a leading car or locomotive, the detection of current indicates which end, the A or B end, is attached to the power source. An example of an electrical current monitoring device includes, but is not limited to, the use of an eddy current device, for example a current transformer (current transducer). One current monitoring device is mounted at the A end, the other at the B end of the rail car. This device generates an electrical signal when linked to the power source of the preceding car or locomotive. As only one end of the rail car is linked to the power source, for example the A end, the resulting signal may be used to determine which end of the rail car is forward.

[0045] Figure 3 is a non-limiting top view of a delivery system (100) mounted on a freight car. Circulation equipment (160) and electrical equipment (150) may be mounted on one or both sides of the reservoir (120). The system (100), including the reservoir (120), metering and dispensing equipment (160), and control (electrical) system (150), is preferably covered to protect it from payload material as well as debris that can potentially impact on the performance of the equipment. The components of the delivery system (100) may be attached to the frame of the rail car, or attached to the bed of container that is attached to the frame of the car (for example see frame supports 185, Figures 4, 7 and 8).

[0046] The delivery system (100) of the present invention is also able to withstand tipping of the freight car through an angle from about 90° to about 165° or any angle therebetween, for example, when the payload is being discharged from the rail car.

[0047] A non-limiting side view of a reservoir (120) is shown in Figure 4, and non-limiting end views of the circulation and electrical equipment housing (150, 160, respectively) are shown in Figures 5 and 6. The reservoir (120) may have a working capacity of about 50 to about 500 US gallons (about 200 to about 2000 liters), depending upon the space available. Preferably, the volume of the reservoir (120) is from about 100 to about 300 gallons (about 400 to about 1200 liters), more preferably about 200 gallons (about 750 liters). The reservoir (120) is fitted with inlet and outlet ports to allow transfer of fluid from the reservoir to the circulation pump (164) and back as required. The reservoir (120) is also preferably fitted with baffles (124) to reduce movement of the liquid composition within the reservoir, and stiffeners (182). The reservoir (120) may be enclosed in a frame (180; Figure 7) and insulated to retain heat as required. The reservoir (120) may be fitted with a pressure relief valve (126), a

vacuum break (128), a liquid volume-indicating device for example a mechanical float valve (122), a series of level switches to monitor fluid level, or both, and a temperature switch.

- 5 **[0048]** To maintain an appropriate temperature of the composition within the delivery system (100) when used in cold climates, the reservoir (120) may be outfitted with one or more than one heat blanket, located on the bottom of the reservoir (120), for example but not limited to silicone rubber heat blankets, and the reservoir (120) may be insulated. Dispensing lines, including the pipe system (163), supply lines (158) delivery lines (166) and nozzle assemblies (220) may also be heat traced and insulated as required. Main electrical enclosures (e.g. 150), and the dispensing and metering system (160) may contain radiant heat sources and they may be insulated to prevent heat loss. The heating system may be controlled by a temperature sensor. The temperature sensor activates the heating system when ambient temperature drops below a certain preset temperature. Additionally, the heating system may be monitored and actuated remotely.
- 10 **[0049]** Referring to figures 9 to 11, a nozzle assembly (220) is mounted to the rail car in any suitable manner that positions the nozzle assembly (220) in a position close to the top of the rail track. For example which is not to be considered limiting, the nozzle assembly (220) may be mounted to a frame (140) via a bracket (e.g. 200). The nozzle assembly (220) may comprise one or more than one nozzle as required. The examples in Figures 9-11 show a nozzle assembly (220) comprising one nozzle. However, additional nozzles may be present in the nozzle assembly (220) if the top and the side of the rail-head (gauge face of rail) are to receive the same or different liquid composition. A nozzle such as that described in WO 03/099449 may be used. The distance between nozzle and top of the rail (210) is preferably between about 0.5 and about 5 inches (about 10 to about 80 cm), more preferably, from about 2 to about 4 inches (about 30 to about 60 cm). Adjustable brackets may be used to, for example, compensate for differences in wheel diameters in different rail cars, or due to decrease diameters resulting from wear.
- 15 **[0050]** To maintain elevated temperature during use in low temperature environments, the nozzle dispensing enclosures may contain radiant heat sources or cartridge heaters. The dispensing nozzle enclosures may also be insulated to prevent heat loss, for example using a sprayable air cured polyurethane foam or sheet polystyrene. The heating system of the nozzle may be controlled by a temperature sensor that is activated when ambient temperature drops below a certain preset temperature. Furthermore, heating system of the nozzle may be controlled by a temperature sensor that is activated remotely.
- 20 **[0051]** The liquid composition is transported from the reservoir (12) to the nozzle assembly (220) by a metering pump housed within one or more than one dispensing and metering system (160). The dispensing system may comprise one or more than one pump, for example a

pump for each side of the rail car as shown in Figures 5 and 6. Fluid supply to the one or more than one pump can be controlled by an electrically actuated solenoid valve. Pump speed can further be correlated to car speed in order that the same amount of fluid is applied to the railhead. Furthermore, pump speed may be monitored and regulated remotely.

[0052] The application of the liquid composition is preferably in the form of atomized spray by using pressurized air that can be supplied by the locomotive to either end of the rail car, or a compressor on board of the rail car. The air pressure may be for example, which is not to be considered limiting, from about 40 to about 80 psi, and remains constant regardless of car speed. The air pressure may be turned on and off using one or more than one electrically actuated solenoid valve. The solenoid valves and air pressure may be monitored and adjusted remotely if desired. The liquid can also be applied through a pump without the use of pressurized air. However, it is also to be understood that other methods of applying the liquid composition to the surface of the rail may be used as many sets of non-driving wheels will pass over the film, and the need for film quality and drying time is not a critical variable.

[0053] Power for the dispensing equipment can be derived from a locomotive, and provided to the rail car from either end of the car. Alternatively, power can also be generated from a generator located onboard the rail car, or from a generator driven from the wheels of the rail car.

[0054] Any liquid composition that can be pumped from the reservoir to a nozzle may be applied using the system of the present invention. Non-limiting examples of liquid compositions that may be applied include those described in US 6,136,757, US 2004 0 038 831 A1; and WO 02/26919 (US 2003 0 195 123 A1).

[0055] Therefore, the present invention also provides a liquid composition application system mounted on a rail car comprising:

- i. one or more than one reservoir for holding a liquid composition;
- ii. a pipe connected to the one or more than one reservoir; and
- iii. a pump, in fluid communication with the pipe, for moving the liquid composition from the one or more than one reservoir to one or more than one dispensing nozzle.

[0056] Furthermore, the present invention pertains to a rail car, comprising a liquid composition application system, the liquid composition application system comprising:

- i. one or more than one reservoir for holding a liquid composition;

ii. a pipe connected to the one or more than one reservoir; and

iii. a pump, in fluid communication with the pipe, for moving the liquid composition from the one or more than one reservoir to one or more than one dispensing nozzle.

[0057] In order to ensure that the liquid composition is applied at the appropriate location along the rail system, for example along curved portions of track, a system is required to detect curves, changes in elevation, or other features or location of the track. For example, which is not to be considered limiting, Figure 12A illustrates a railway track with a curvature. Three railway cars (250) are shown as they are traveling at a translation rate "v" through a curved track (230), which has a radius "R". The track curvature C is the reciprocal of the radius R.

[0058] Figure 12B illustrates a pair of railcar wheels (130) on a track in a left-hand turn curvature. The centrifugal force (260; C_f) on a railway car traveling at a speed "v" in a curvature with a radius "R" can be calculated as:

$$C_f = (m \cdot v^2)/R,$$

whereby the "m" is the mass of the railway car. The force will cause the profiled wheel flange to contact the inside surface of the outside rail, or the high rail (270; the inside rail is called low rail, 280). The region of maximum wear is indicated as 290. During the movement through a curvature, a train consist may need different amounts or different types of friction modifier to reduce squeal or increase frictional contact with the surface of the rail. Similarly, when a train consist moves through a rail with inclining or declining segment of tracks, or within urban v. rural areas, different amounts or different types of friction modifier or liquid compositions may also be required.

[0059] In order to regulate, monitor, or both regulate and monitor, the amount and rate of application of a liquid composition on the rail, the delivery system of the present invention may include a control system which has a PLC (programmable logic controller), a microprocessor, or a computer, based system and optionally a GPS (global position system) receiver with antenna, or other curve or elevation detection system. Furthermore, one or more than one transmitting and receiving systems, for example, a radio frequency (RF) transceiver, may also be used to obtain data about the train, rail car, track features, train location, operational parameters of the rail car or the composition delivery system, or a combination thereof, as required. The controller may be located on the railcar and interfaced with the GPS, RF transceiver, operate and collect data locally on the rail car, or a combination thereof. The PLC may be any suitable type, depending upon what system is presently being used with a rail system. Non-limiting examples of suppliers of a PLC include GE, Allen-

Bradley (Division of Rockwell Automation), or Siemens. The controller may also be used to detect, transmit, receive or process any required information, for example data regarding whether train is loaded or empty, whether the train is accelerating or braking, temperature, the rate of usage of the liquid composition, or other data relating to the delivery system, for example system pressure and temperature.

[0060] A controller may also be operatively connected to any rail curve, rail elevation, track feature or other detection device, for example to identify whether the train is within an urban or rural area, in a tunnel, on an incline.

[0061] A GPS system (see 300, Figure 13), a radio frequency (RF) transceiver, for example a narrow or broadband RF transceiver (RFT; 300, Figure 13), or both, may be used. The curve, elevation, track feature, or train location, train condition detection system, for example a GPS, RF transceiver, or both, may be located on the rail car, or the locomotive. If located on the locomotive, then the information from the system is operatively linked to the control and delivery system on the rail car. The GPS, RF transceiver, or both, may also be located on the rail car so that the information of the topology, elevation, track features, train features or other data that may be used with the liquid composition delivery system of the present invention may be operated independently from the locomotive. In this way a suitably outfitted rail car may be used with any train consist and can be readily interchanged between train consists.

[0062] The control system may control the dispensation if a low tank level switch is activated, and shuts down fluid dispensation if high pressure is detected in the dispensing system. The control system may also switch off the fluid dispensation if a specific drop in brake pipe pressure is determined, or if atomizing air pressure is lost. The control system may also modify the rate of application of the liquid to the rail surface. Furthermore, the system will ensure that the fluid composition is not applied to a rail surface below a pre-specified speed, for example the delivery system is shut off below about 5, about 7, or about 10 mph. This avoids application to a rail surface when cars are being shunted in a yard. The control system may be used to limit application of the composition within urban or rural areas if required. The control system may also maintain a minimum level of fluid in the tank for heating purposes and it may shutdown if a low fluid level alarm in the tank is activated. Non-limiting examples of devices that may be used to monitor tank level include ultrasonic sensors, for example a LU12-5001 (MiniMe two wire ultrasonic transmitter, available from Flowline, Los Alamitos CA), or hydrostatic sensors, for example a 3000, 4000, 47000 or 5000series low pressure transducer (available from Gems Sensor, Plainville CT). However, other devices that detect tanks levels directly or indirectly may also be used.

[0063] The control system may have an operator-actuated interface, for example a touch screen, or it may be operated remotely using for example an RF transceiv-

er, for example but not limited to a narrow or broadband transceiver such as a 900Mhz, or other frequency, wireless broadband RF transceiver, or the rail car may be accessed locally and remotely. Information relating to the

5 delivery system within a rail car, the rail car, and other data of interest, may be obtained from the delivery system from a local information panel, touch screen or other similar system, accessed remotely using a suitable transceiver, or both accessed locally at the rail car, or remotely 10 at a location separate from the rail car or train consist, as required. Supervisory reports, alarm history, or summaries of the data may be accessed on a continuous or regular basis, and further detailed reports obtained as required. The following non-limiting examples outline 15 some of the information flow that may be monitored. However one of skill in the art would understand that other operating data may also be obtained:

Non-limiting examples of Quick Panel Tasks

- 20
- [0064]**
1. Rail car housing the composition delivery system of the present invention arrives on site and network may be established.
 - a. Compile .sum file. This file may be an XML file that will give a Supervisory summary for the trip. This Supervisory summary typically includes:
 - i. The car number
 - ii. Trip date time of start and finish
 - iii. Status of car at finish
 - iv. Number of alarms at finish
 - v. Tank start level
 - vi. Tank End level
 - vii. Tank usage for trip
 - b. Push .sum file to server.
 - c. Push .alm file (xml file containing alarms) to server.
 - d. Attempt to push any DAT and DAX files to server (only new files will be pushed, see section on Status Web Service).
 2. If information is being accessed remotely, then when a train enters into a good network status area and is connected to network the following process may take place (these may be monitored locally, remotely, or both):
 - a. Request from the server, the most recent files that the server has regarding this car.
 - b. System's may push any outstanding .sum and .alm files to the server, as required.
 - c. Systems may also push any outstanding .DAT and .DAX files to the server,

if desired.

d. All movements may be logged to any suitable memory medium for example, flash card disk, CD, or other disc, in a desired file format, for example as a text file. Preferably the movements are tagged or dated in some manner.

Non-Limiting example of Server Application

[0065]

1. Handle newly arrived files application (handle-Files.exe)

- a. Moves any .alm and .sum files into their appropriate directories so they can be viewed from web site.
- b. Updates registry with dates of most recent .sum files and .dat files

2. Evaluate .sum files application (evaluate.exe)

- a. Accesses .sum files and determines whether an email notification needs to be sent.
- b. Configures email destinations (addresses) and determine email delivery to designated sites and for what values

3. Status Web Service (StatusWS)

- a. Presents information stored in the registry to the network as a web service.
- b. Each rail car will be able to request what information regarding itself the server has.

4. Email notification Service application (Email.exe)

- a. A generic console application may be passed an email destination address, a body and a subject. This application sends the appropriate email, and logs it to a text file on the server.
- b. This application may be configurable so the Sender and the SMTP server can be changed. These values may also be saved in the server's registry.

5. Web Portal allowing for easy viewing of summaries

- a. A web portal may be created that will give the user access to all summaries (e.g. sorted and grouped by date) as well as all alarm logs.
- b. Each alarm log will represent a period of time, for example, a 24 hour period.
- c. Each summary may represent the amount of time it has taken for a full trip to be made.

d. All summaries may have hyperlinks to alarm logs that relate to the dates of the trip.

[0066] Topological information of a railway may be acquired or stored in different ways. Figure 13 illustrates a system where the topological information acquired from different sources is used to control the application of liquid composition. One source for acquiring topological information along a rail system is a global positioning system (GPS; 300). In this system, an antenna is mounted at a fixed location, for example at one end, of the rail car. The rail car further comprises a GPS receiver within the electrical equipment (150; Figures 3 and 6). The GPS streams data (for example, conforming to NEMA; National Electrical Manufacturers Association) to the PLC including latitude, longitude, speed, heading and altitude. The GPS (300) may provide the rail car speed that can be used to control the dispensing pump application rate, or changes in position of the rail car that can be used to determine whether or not the rail car is negotiating a curved portion of track, or the severity of the curvature of the track, and alter the amounts of liquid composition provides to the surface of the track.

[0067] The information from the GPS (300), RF transceiver (RFT; 300), or both is received by a computer, PLC, or microprocessor (350) which may comprise a database (340) of the topology information about the railway the train consist is traveling, for example, curvature of the track, degrees of track curvature for example mild, medium or sharp curves, whether there are changes in elevation of the track, identify track features, for example, a bridge, a tunnel, switches, urban or rural areas, and the like. Additionally, the car speed or other operational parameters, for example, but not limited to system pressure, ambient temperature, may also be monitored. The GPS will provide a location of the train consist along the railway and other track features, thereby allowing the computer (350) to control the liquid composition application devices (e.g. 360, 380) independently or together.

[0068] Data obtained about the liquid supply system located on the rail car may be sampled periodically, for example at set times as required, or following the change of state of the parameter. The data being sampled, selected aspects of the sampled data, alarm history, supervisory reports, or a combination thereof, may be stored locally on the rail car on a suitable storage device, for example but not limited to a flash card, CD or disc and accessed as required, or the data being sampled may be delivered to a remote site via the RF transceiver and monitored at this site.

[0069] The GPS system, the RF transceiver, or both, may be located on the rail car, or the locomotive. If located on the locomotive, then the information from the GPS system may be operatively linked to the control and delivery system on the rail car. If located on the rail car the information from the GPS system may be directly used with the control and delivery system on the rail car and the rail car independently monitored from the locomotive.

[0070] With reference to Figure 14, there is shown an example of data for tank levels of a liquid composition application system in a rail car. Such data may be obtained remotely or locally and can be used to monitor consumption levels, application rates, or both of the liquid composition in real time. Additionally, alarms may be recorded to ensure that adequate levels of liquid composition are maintained within the delivery system. The monitoring period may be made for any appropriate duration, for example sampling on continuous, a per-trip, hourly, daily weekly or monthly basis, on a change of state basis, or other desired basis, depending upon use.

[0071] As indicated above, the GPS system may also be used along with an RF transceiver system for monitoring the delivery of the composition along the track, and for remote sensing of the delivery system properties, for example, fluid level within the tank or reservoir, temperature of rail car, track, tank or delivery system nozzle, pressure of the system, the speed of the train and the like.

[0072] The GPS may also calculate the topology information in real-time. For example if the direction of the train consist is changing due to a curve then sampling of GPS data can be used to determine the occurrence of a curve in the track, and the rate of application of the liquid composition to the rail adjusted accordingly. In this case, the computer may instruct one or more than one application devices to apply one or more than one liquid compositions to the gauge face of an outside rail (high rail), to the top surface of the inside rail, or both. Furthermore, different curve severities may also be monitored, for example, mild, medium and sharp curves, and the amount of liquid composition applied to the rail surface may be adjusted accordingly. For example, greater amounts of composition may be applied on sharper curves than on mild curves.

[0073] If the elevation of a train is increasing or decreasing in a given time interval, the train consist may be on an inclining or declining segment of a rail, respectively, and the appropriate dispensation of liquid composition provided to the track. This will ensure that the composition is not being applied to the track during a time when train braking is occurring, for example, going down an incline.

[0074] Similarly, the dispensation of the liquid composition may be modified depending upon the track features encountered by the train and identified by the GPS, for example, a bridge, a tunnel, switches and the like.

[0075] The information of the topology on a railway can also be obtained from a Geographic Information System (GIS). GIS is a system of computer software, hardware and data, to help manipulate, analyze and present information that is tied to a spatial location, usually a geographic location. The topology information of a railway may also include the incline and decline of the rail. Accordingly, the computer may instruct one or more than one application devices to apply one or more than one liquid compositions to the rail.

[0076] Another method of measuring the curvature of

a rail is to compare the speed of a pair of wheels on each side of the train (310), if the speed of one wheel is higher than the other, this may indicate a curvature on the railway. In this situation, the computer (350) may instruct for the application of liquid composition for example to the gauge face on side of the rail car exhibiting the increased wheel speed (the high or outside rail), the low rail (traveling at a lower speed), or both.

[0077] Alternatively, a rail-width detection system, for example but not limited to a camera-based, or laser-based, rail-width detection system, may be employed that can detect changes in the distance between the rails. As a train consist passes through a curve, the distance between the rails increases due to deflection by the outside rail. Any system that can detect this change in inter-rail distance may be employed.

[0078] Another method of measuring the curvature or inclination in a rail system is through the use of a position-sensing device, for example one or more than one gyroscope (320), or proximity probes (330). A gyroscope can measure both the yaw rate and the attitude of a train consist. Proximity probes may detect position shifts within a rail car as the car enters and exists a curve. Therefore, the input from a gyroscope or other position-sensing device can be used to control the liquid composition application devices.

[0079] Other devices (330) may also provide information of the curvature or inclination of the track, for example, operator derived information, for example train speed, orientation of the rail car, or manual inputs relating to curvature, or remotely obtained data about the delivery system of the present invention including levels of the composition within the tank, temperature of the car and track, and this information may then be used by the computer to control the application rate of the liquid composition as required, activate heaters to ensure the tank and nozzle do not freeze, log data about the delivery system in general, application rates, down-load car supervisory reports, logged alarms, and the like.

[0080] Therefore, the present invention provides a method for applying a liquid composition in a railway system, comprising the steps of:

- 45 i. supplying the liquid composition in one or more than one reservoir on board a train consist;
- ii. receiving topological information from a topographical device on board the train consist;
- 50 iii. processing the topological information received from the topographical device using a processing device to produce processed topological information; and
- 55 iv. applying the liquid composition from one car within the train consist to a rail surface within the rail system according to the processed topological information.

[0081] The device may be a computer, PLC or microprocessor, and further comprise a GPS that provides real-time topological information to the device for controlling the application of the liquid composition to the rail surface. A database having topology information of the railway system may also be included within the device, and the device coordinates the information from the GPS with the database information for controlling the application of the liquid composition to the rail surface. Additionally, the device may comprise a wheel speed monitor for determining differential speed of a pair of wheels located on opposite side of a car within the train consist; where a difference in the wheel speed is used to determine curvature in the rail system, and control the application of the liquid composition to the rail surface. A rail-width detection system may also be employed that can detect changes in the distance between the rails due to deflection of the outside rail within a curve. Furthermore, a gyroscopic device may be used to determine topological information of the railway system and provide this information to the device for controlling the application of the liquid composition to the rail surface.

[0082] Alternatively, the rail car delivery system of the present invention may also be operatively linked to a control system within a locomotive, where the electrical components, or the controller system, in the rail car receives instructions from a locomotive control circuit. These instructions are then used to regulate the delivery system of the rail car. The locomotive control system may be used to 1) process changes in topological information in the rail system, for example using a GPS or other rail topological sensing systems as described herein; 2) control the dispensing system as required using information obtained from evaluation of rail topological data, for example but not limited to, orientation of the rail car, speed of the rail car, curve sensing, sensing severity of a curve, or changes in elevation, to regulate composition delivery to one or both of the tracks, to the top or gauge-face of the rail, or both; 3) monitoring pressure, temperature, valve status, pump status and other circulation parameters within the reservoir, pipe system, supply lines, circulation pump, metering pump(s), filter(s), and nozzle assemblies; 4) controlling the heating system as required within the reservoir, pipe system, supply lines, circulation pump, metering pump(s), filter(s), and nozzle assemblies; 5) regulating the metering pump output with respect to rail car speed, to ensure a consistent amount of the fluid composition is applied to the railhead; 6) controlling dispensation of the fluid composition for example if a low tank level switch is activated, shuts down fluid dispensation if high pressure is detected in the dispensing system, switches off the fluid dispensation if a specific drop in brake pipe pressure is determined, or if atomizing air pressure is lost; 7) shutting of the delivery system below a threshold rail car speed; 8) determining the orientation of the rail car within respect to the train consist; and 9) a combination of the above.

[0083] Additionally, the rail car delivery system of the

present invention may also be operatively linked to a control system that is monitored and accessed remotely, where the electrical components, or the controller system, in the rail car send and receive instructions from a system separate from the rail car or train consist. In this example, the remote system may access and monitor system data, send operational instructions to the delivery system regulate the system, or both. The remotely control system may be used to:

- 10 - record changes in topological information in the rail system, as received from for example a GPS or other rail topological sensing systems as described herein located on the rail car;
- 15 - monitor, control, or both monitor and control the dispensing system as required using information obtained from evaluation of rail topological data, for example but not limited to, orientation of the rail car, speed of the rail car, sensing severity of a curve, curve sensing, changes in elevation, to regulate composition delivery to one or both of the tracks, to the top or gauge-face of the rail, or both;
- 20 - monitoring pressure, temperature, valve status, pump status and other circulation parameters within the reservoir, pipe system, supply lines, circulation pump, metering pump(s), filter(s), and nozzle assemblies;
- 25 - controlling the heating system as required within the reservoir, pipe system, supply lines, circulation pump, metering pump(s), filter(s), and nozzle assemblies;
- 30 - 35 - monitor, regulate, or both monitor and regulate the metering pump output with respect to rail car speed, to ensure a consistent amount of the fluid composition is applied to the railhead;
- 40 - monitor, control, or both monitor and control dispensation of the fluid composition for example if a low tank level switch is activated, shuts down fluid dispensation if high pressure is detected in the dispensing system, switches off the fluid dispensation if a specific drop in brake pipe pressure is determined, or if atomizing air pressure is lost;
- 45 - 50 - shutting of the delivery system below a threshold rail car speed, or within certain urban areas;
- determining the orientation of the rail car within respect to the train consist; and
- 55 - a combination of the above.

[0084] The present invention has been described with regard to one or more embodiments. However, it will be

apparent to persons skilled in the art that a number of variations and modifications can be made without departing from the scope of the invention as defined in the claims.

Claims

1. A device for applying a liquid composition to a rail surface (100), comprising:

- i. means for acquiring topological information of a rail system in real-time;
- ii. means for applying the liquid composition to the rail surface; and
- iii. a processing device for receiving the topological information, and controlling application of the liquid composition, wherein control of the application of the liquid composition is based on the topological information received by the processing device;

characterised in that the means for acquiring topological information comprises only one global position system (300) and the topological information comprises speed, a change in direction, and/or a change in elevation.

2. The device of claim 1, wherein the means for acquiring topological information further comprises a device for determining the speed of a pair of wheels (310), one or more than one gyroscope (320), one or more than one proximity probe (330), and/or a rail width detection system.
3. The device of claim 1 or 2, wherein the topological information comprises the speed of a rail car (110) in the rail system and the processing device controls a rate of application of the liquid composition accordingly.
4. The device of claim 1 or 2, wherein the topological information comprises the change of direction of a rail car (110) in the rail system to determine whether or not the rail car (110) is negotiating a curved portion of a rail track in the rail system and the processing device controls application of the liquid composition accordingly.
5. The device of claim 1 or 2, wherein the topological information comprises the change in elevation of a rail car (110) in the rail system to determine whether or not the rail car (110) is negotiating an inclining or declining segment of a rail track in the rail system and the processing device controls application of the liquid composition accordingly.
6. The device according to any preceding claim, where-

in the means for applying the liquid composition to the rail surface comprises:

- 5 i. one or more than one reservoir (120) for holding the liquid composition;
- 10 ii. a pipe (163) connected to the one or more than one reservoir (120);
- 15 iii. one or more than one dispensing nozzle assembly (220); and
- iv. a pump (164), in fluid communication with the pipe (163), for moving the liquid composition from the one or more than one reservoir (120) to the one or more than one dispensing nozzle assembly (220).
- 20 7. The device of claim 6, further comprising a source of pressurized air connected to the one or more than one dispensing nozzle assembly (220) to dispense the liquid composition as an atomized spray.
- 25 8. The device of claim 6 or 7, wherein the processing device comprises a metering device for controlling operation of the pump (164).
- 30 9. The device according to any preceding claim, wherein the processing device comprises a controller (350) that processes the topological information, data from the means for applying the liquid composition to the rail surface, or both the topological information and data from the means for applying the liquid composition to the rail surface.
- 35 10. The device of claim 9, wherein the controller is connectable to a locomotive control circuit, and wherein the controller operates in response thereto.
- 40 11. The device of claim 9, wherein the controller is accessed remotely from a site separate from the rail car (110).
- 45 12. The device according to any of claims 9 to 11, wherein the controller is selected from the group consisting of a programmable logic controller, a microprocessor and a computer.
- 50 13. The device according to any of claims 9 to 12, wherein the controller has an operator-actuated interface.
- 55 14. The device according to any preceding claim, wherein the means for applying the liquid composition to the rail surface is provided on a rail car (110) of a train consist.
15. A method for applying a liquid composition in a rail system, **characterized by** the steps of:
 - i. providing the device of any of claims 1 to 14;
 - ii. acquiring the topological information of the rail

- system in real-time using the topological device;
- iii. processing the topological information and controlling the application of the liquid composition using the processing device, wherein control of the application of the liquid composition is based on the topological information received by the processing device.
- 16.** The method according to claim 15, wherein the liquid composition is applied to a curved section of a rail in the rail system, a tangent section of the rail, or both the curved section of the rail and the tangent section of the rail.
- 17.** The method of claim 15, wherein the liquid composition is applied to the top of a rail in the rail system, to a side of a railhead of the rail, or both to the top of the rail and to the side of the railhead.
- 18.** The method of claim 17, wherein the liquid composition is applied to the top of the rail.
- 19.** The method of claim 17, wherein the liquid composition is applied to both the top of the rail and to the side of the railhead.

Patentansprüche

- 1.** Vorrichtung zum Aufbringen einer Flüssigkeitszusammensetzung auf eine Schienenoberfläche (100) umfassend:
- i. Mittel zum Erfassen von topologischen Informationen eines Schienensystems in Echtzeit;
 - ii. Mittel zum Aufbringen der Flüssigkeitszusammensetzung auf die Schienenoberfläche; und
 - iii. eine Verarbeitungseinrichtung zum Empfangen der topologischen Informationen und zur Regelung des Aufbringens der Flüssigkeitszusammensetzung, wobei die Regelung des Aufbringens der Flüssigkeitszusammensetzung auf den von der Verarbeitungseinrichtung empfangenen topologischen Informationen basiert;
- dadurch gekennzeichnet, dass**
die Mittel zum Erfassen von topologischen Informationen nur ein Globales Positions-System (300) umfassen und die topologische Informationen die Geschwindigkeit, eine Richtungsänderung und/oder eine Änderung der Höhe umfassen.
- 2.** Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** die Mittel zum Erfassen von topologischen Informationen zusätzlich eine Vorrichtung zur Bestimmung der Geschwindigkeit eines Räderpaars (310), ein oder mehr als ein Gyroskop (320), einen oder mehr als einen Abstandssensor (330) und/
- oder ein System zur Detektion der Schienenbreite umfassen.
- 3.** Vorrichtung nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** die topologischen Informationen die Geschwindigkeit eines Schienenfahrzeugs (110) im Schienensystem umfassen und die Verarbeitungseinrichtung den Grad des Aufbringens der Flüssigkeitszusammensetzung entsprechend regelt.
- 4.** Vorrichtung nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** die topologischen Informationen Richtungsänderungen des Schienenfahrzeugs (110) im Schienensystem umfassen, um zu bestimmen ob das Schienenfahrzeug (110) einen gekrümmten Abschnitt eines Schienenstrangs im Schienensystem überwindet oder nicht und die Verarbeitungseinrichtung das Aufbringen der Flüssigkeitszusammensetzung entsprechend regelt.
- 5.** Vorrichtung nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** die topologischen Informationen Höhenänderungen des Schienenfahrzeugs (110) im Schienensystem umfassen, um zu bestimmen ob das Schienenfahrzeug (110) einen steigenden oder sich senkenden Abschnitt eines Schienenstrangs im Schienensystem überwindet oder nicht und die Verarbeitungseinrichtung das Aufbringen der Flüssigkeitszusammensetzung entsprechend regelt.
- 6.** Vorrichtung nach einem der vorangehenden Ansprüche, **dadurch gekennzeichnet, dass** die Mittel zum Aufbringen der Flüssigkeitszusammensetzung auf die Schienenoberfläche umfassen:
- i. einen oder mehrere Behälter (120) zur Aufnahme der Flüssigkeitszusammensetzung;
 - ii. ein Rohr (163), welches mit dem einen oder den mehreren Behältern (120) verbunden ist;
 - iii. eine oder mehrere Spenderdüseneinrichtungen (220); und
 - iv. eine Pumpe (164), in Fluidverbindung mit dem Rohr (163), zum Fördern der Flüssigkeitszusammensetzung aus dem einen oder mehr als einen Behälter (120) an eine oder mehrere Spenderdüseneinrichtungen (220).
- 7.** Vorrichtung nach Anspruch 6, **dadurch gekennzeichnet, dass** die Vorrichtung zusätzlich eine Druckluftquelle umfasst, welche mit der einen oder mehr als einen Spenderdüseneinrichtung (220) verbunden ist, um die Flüssigkeitszusammensetzung als Sprühnebel zu verteilen.
- 8.** Vorrichtung nach Anspruch 6 oder 7, **dadurch gekennzeichnet, dass** die Verarbeitungseinrichtung

- eine Messvorrichtung zur Regelung des Betriebs der Pumpe (164) umfasst.
9. Vorrichtung nach einem der vorangehenden Ansprüche, **dadurch gekennzeichnet, dass** die Verarbeitungseinrichtung einen Regler (350) umfasst, welcher die topologischen Informationen oder Daten von den Mitteln zum Aufbringen der Flüssigkeitszusammensetzung auf die Schienenoberfläche oder beides, die topologischen Informationen und Daten von den Mitteln zum Aufbringen der Flüssigkeitszusammensetzung auf die Schienenoberfläche verarbeitet. 5
10. Vorrichtung nach Anspruch 9, **dadurch gekennzeichnet, dass** der Regler mit einem Lokomotiven-Regelkreis verbindbar ist, wobei der Regler in Reaktion zu diesem betrieben wird. 10
11. Vorrichtung nach Anspruch 9, **dadurch gekennzeichnet, dass** der Regler mittels Fernzugriff von einem von dem Schienenfahrzeug (110) getrennten Ort bedient wird. 15
12. Vorrichtung nach einem der Ansprüche 9 bis 11, **dadurch gekennzeichnet, dass** der Regler aus der Gruppe bestehend aus einer speicherprogrammierbaren Steuerung, einem Mikroprozessor und einem Computer ausgewählt ist. 20
13. Vorrichtung nach einem der Ansprüche 9 bis 12, **dadurch gekennzeichnet, dass** der Regler eine vom Operateur betätigte Schnittstelle hat. 25
14. Vorrichtung nach einem der vorangehenden Ansprüche, **dadurch gekennzeichnet, dass** die Mittel zum Aufbringen der Flüssigkeitszusammensetzung auf die Schienenoberfläche auf einem Schienenfahrzeug (110) einer Zugzusammensetzung zur Verfügung gestellt werden. 30
15. Verfahren zum Aufbringen einer Flüssigkeitszusammensetzung in einem Schienensystem, **gekennzeichnet durch** die Schritte: 35
- i. zur Verfügungstellen der Vorrichtung nach einem der Ansprüche 1 bis 14;
 - ii. Erfassen der topologischen Informationen eines Schienensystems in Echtzeit mittels der topologischen Vorrichtung;
 - iii. Verarbeiten der topologischen Informationen und Regelung des Aufbringens der Flüssigkeitszusammensetzung unter Verwendung der Verarbeitungseinrichtung, wobei die Regelung des Aufbringens der Flüssigkeitszusammensetzung auf den von der Verarbeitungseinrichtung empfangenen topologischen Informationen basiert. 40
16. Verfahren nach Anspruch 15, **dadurch gekennzeichnet, dass** die Flüssigkeitszusammensetzung an einem gekrümmten Abschnitt der Schiene im Schienensystem oder einem Tangentenabschnitt der Schiene oder beides, an einem gekrümmten Abschnitt der Schiene und einem Tangentenabschnitt der Schiene aufgebracht wird. 45
17. Verfahren nach Anspruch 15, **dadurch gekennzeichnet, dass** die Flüssigkeitszusammensetzung auf die Oberseite der Schiene im Schienensystem oder auf eine Seite eines Schienenkopfs der Schiene oder beides, auf die Oberseite der Schiene und auf die Seite des Schienenkopfs aufgebracht wird. 50
18. Verfahren nach Anspruch 17, **dadurch gekennzeichnet, dass** die Flüssigkeitszusammensetzung die Oberseite der Schiene aufgebracht wird. 55
19. Verfahren nach Anspruch 17, **dadurch gekennzeichnet, dass** die Flüssigkeitszusammensetzung auf beides, die Oberseite der Schiene und die Seite eines Schienenkopfs aufgebracht wird.

Revendications

1. Dispositif pour appliquer une composition liquide sur une surface de rail (100), comprenant :
 - i. des moyens destinés à acquérir des informations topologiques d'un système ferroviaire en temps réel ;
 - ii. des moyens destinés à appliquer la composition liquide sur la surface de rail ; et
 - iii. un dispositif de traitement destiné à recevoir les informations topologiques, et commander une application de la composition liquide, dans lequel la commande de l'application de la composition liquide est fondée sur les informations topologiques reçues par le dispositif de traitement ;

caractérisé en ce que les moyens destinés à acquérir des informations topologiques comprennent seulement un système mondial de localisation (300) et les informations topologiques comprennent une vitesse, un changement de direction, et/ou un changement d'élévation. 45
2. Dispositif selon la revendication 1, dans lequel les moyens destinés à acquérir des informations topologiques comprennent en outre un dispositif destiné à déterminer la vitesse d'une paire de roues (310), un ou plusieurs gyroscopes (320), une ou plusieurs sondes de proximité (330), et/ou un système de détection de largeur de rail. 50

3. Dispositif selon la revendication 1 ou 2, dans lequel les informations topologiques comprennent la vitesse d'un véhicule ferroviaire (110) dans le système ferroviaire et le dispositif de traitement commande un taux d'application de la composition liquide en conséquence.
4. Dispositif selon la revendication 1 ou 2, dans lequel les informations topologiques comprennent le changement de direction d'un véhicule ferroviaire (110) dans le système ferroviaire pour déterminer si le véhicule ferroviaire (110) négocie une partie incurvée d'une voie ferrée dans le système ferroviaire ou non et le dispositif de traitement commande une application de la composition liquide en conséquence.
5. Dispositif selon la revendication 1 ou 2, dans lequel les informations topologiques comprennent le changement d'élévation d'un véhicule ferroviaire (110) dans le système ferroviaire pour déterminer si le véhicule ferroviaire (110) négocie un segment d'inclinaison ou de déclinaison d'une voie ferrée dans le système ferroviaire ou non et le dispositif de traitement commande application de la composition liquide en conséquence.
6. Dispositif selon une quelconque revendication précédente, dans lequel les moyens destinés à appliquer la composition liquide sur la surface de rail comprennent :
- i. un ou plusieurs réservoirs (120) destinés à contenir la composition liquide ;
 - ii. un tuyau (163) raccordé au ou aux réservoirs (120) ;
 - iii. un ou plusieurs ensembles de buses de distribution (220) ; et
 - iv. une pompe (164), en communication fluidique avec le tuyau (163), pour déplacer la composition liquide du ou des réservoirs (120) au ou aux ensembles de buses de distribution (220).
7. Dispositif selon la revendication 6, comprenant en outre une source d'air sous pression raccordée au ou aux ensembles de buses de distribution (220) pour distribuer la composition liquide sous forme de pulvérisation atomisée.
8. Dispositif selon la revendication 6 ou 7, dans lequel le dispositif de traitement comprend un dispositif de dosage pour commander le fonctionnement de la pompe (164).
9. Dispositif selon une quelconque revendication précédente, dans lequel le dispositif de traitement comprend un dispositif de commande (350) qui traite les informations topologiques, des données à partir des moyens destinés à appliquer la composition liquide
- 5 sur la surface de rail, ou les informations topologiques ainsi que les données à partir des moyens destinés à appliquer la composition liquide sur la surface de rail.
10. Dispositif selon la revendication 9, dans lequel le dispositif de commande est connectable à un circuit de commande de locomotive, et dans lequel le dispositif de commande fonctionne en réponse à celui-ci.
11. Dispositif selon la revendication 9, dans lequel l'accès au dispositif de commande est réalisé à distance à partir d'un site séparé du véhicule ferroviaire (110).
12. Dispositif selon une quelconque des revendications 9 à 11, dans lequel le dispositif de commande est sélectionné parmi le groupe constitué d'un automate programmable industriel, d'un microprocesseur et d'un ordinateur.
13. Dispositif selon une quelconque des revendications 9 à 12, dans lequel le dispositif de commande comporte une interface actionnée par opérateur.
14. Dispositif selon une quelconque revendication précédente, dans lequel les moyens destinés à appliquer la composition liquide sur la surface de rail sont prévus sur un véhicule ferroviaire (110) d'un train.
15. Procédé pour appliquer une composition liquide dans un système ferroviaire, **caractérisé par** les étapes consistant à :
- i. fournir le dispositif selon une quelconque des revendications 1 à 14 ;
 - ii. acquérir les informations topologiques du système ferroviaire en temps réel en utilisant le dispositif topologique ;
 - iii. traiter les informations topologiques et commander l'application de la composition liquide en utilisant le dispositif de traitement, dans lequel la commande de l'application de la composition liquide est fondée sur les informations topologiques reçues par le dispositif de traitement.
16. Procédé selon la revendication 15, dans lequel la composition liquide est appliquée sur une section incurvée d'un rail dans le système ferroviaire, sur une section tangente du rail, ou sur la section incurvée du rail ainsi que sur la section tangente du rail.
17. Procédé selon la revendication 15, dans lequel la composition liquide est appliquée sur la partie supérieure d'un rail dans le système ferroviaire, sur un côté d'un champignon du rail, ou sur la partie supérieure du rail ainsi que sur le côté du champignon de rail.

18. Procédé selon la revendication 17, dans lequel la composition liquide est appliquée sur la partie supérieure du rail.

19. Procédé selon la revendication 17, dans lequel la composition liquide est appliquée sur la partie supérieure du rail et sur le côté du champignon de rail. 5

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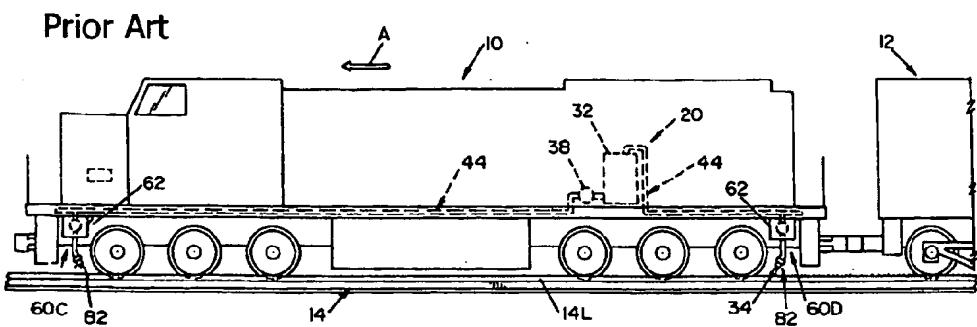


Figure 1, Prior Art

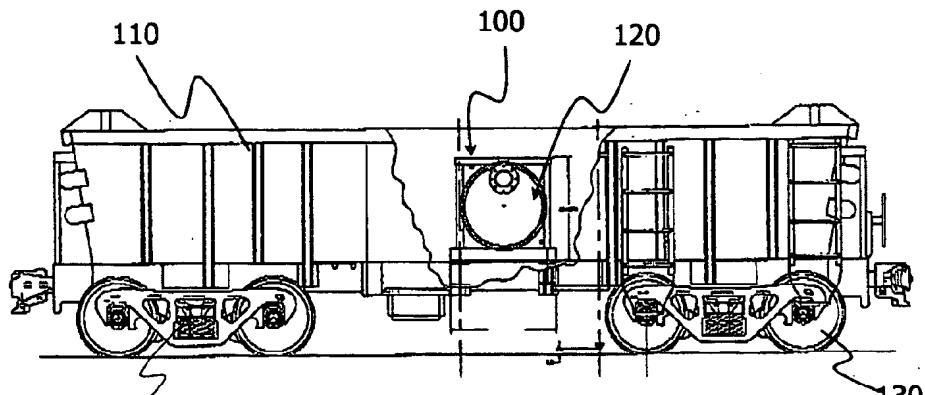


Figure 2

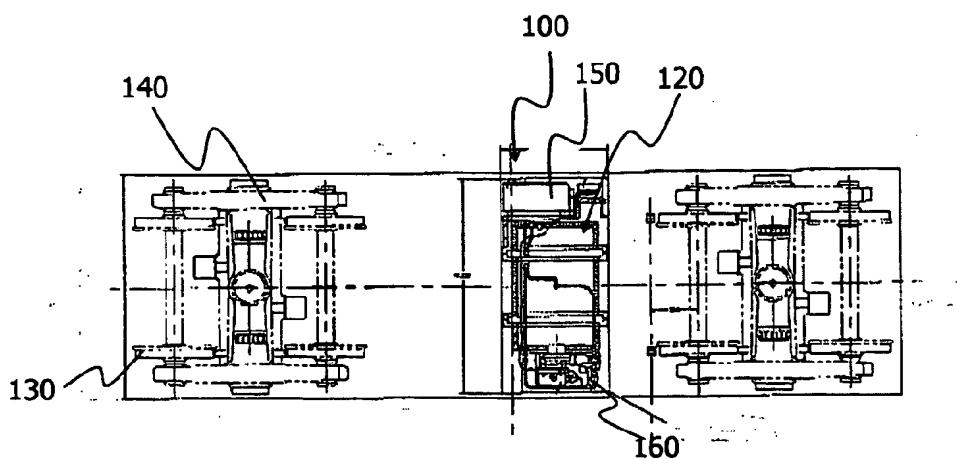


Figure 3

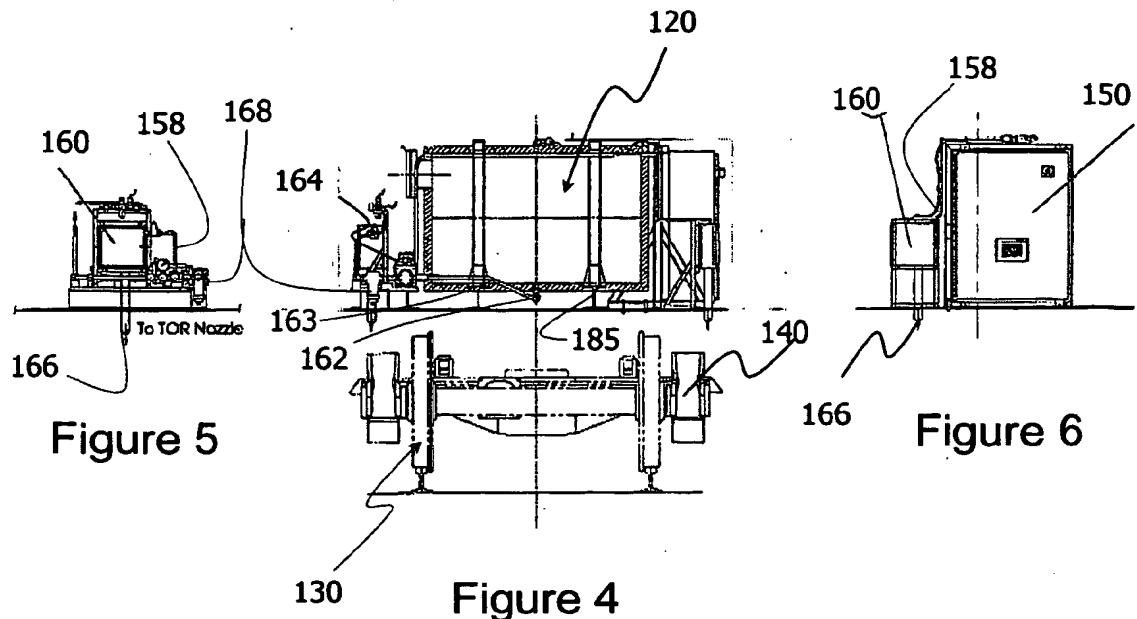
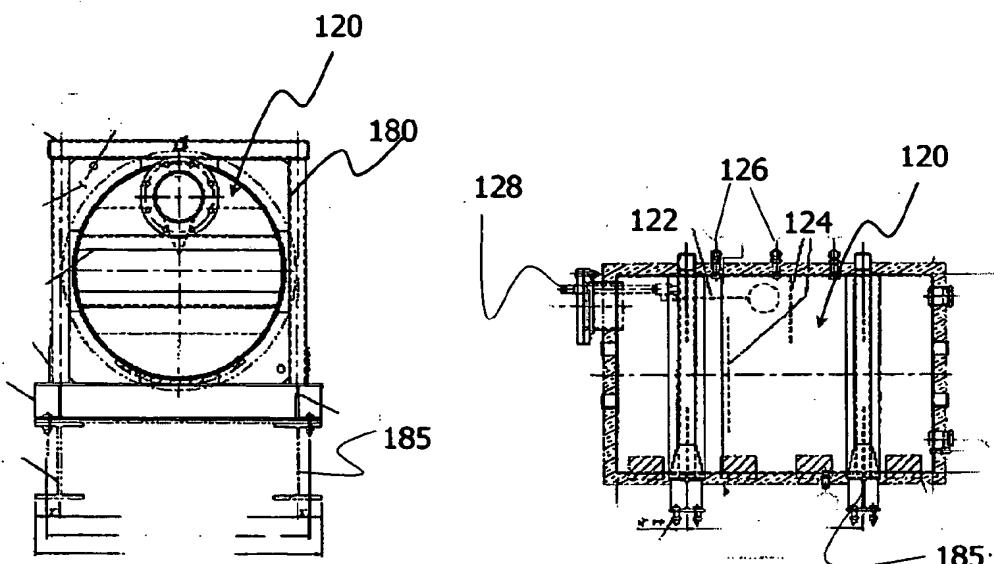


Figure 7

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Figure 8



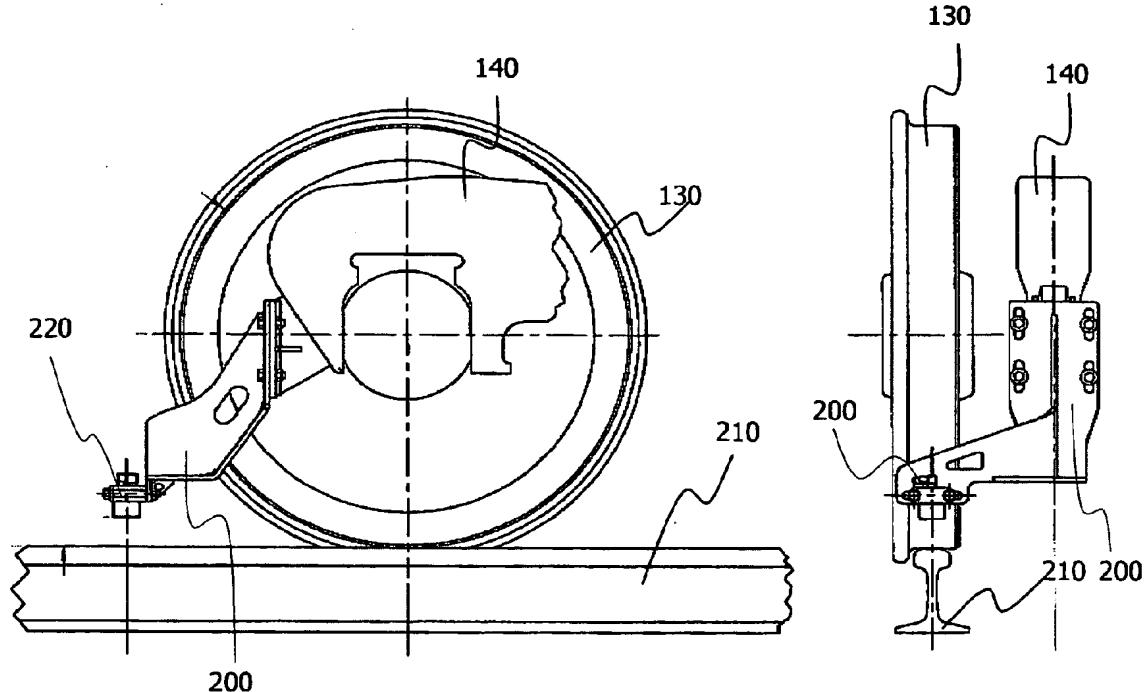


Figure 9

Figure 10

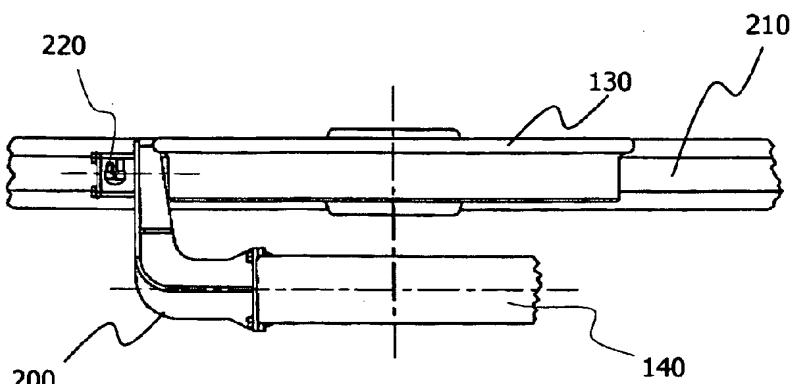


Figure 11

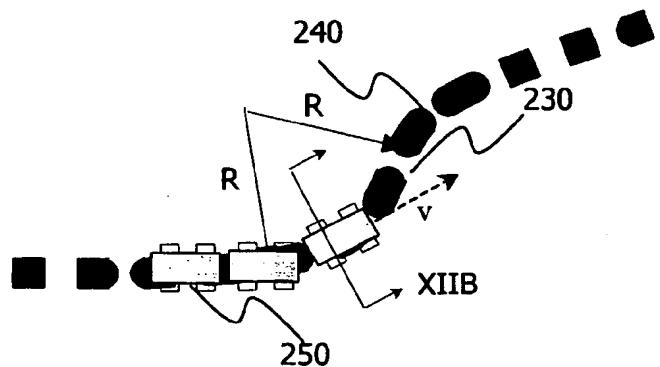


Figure 12A

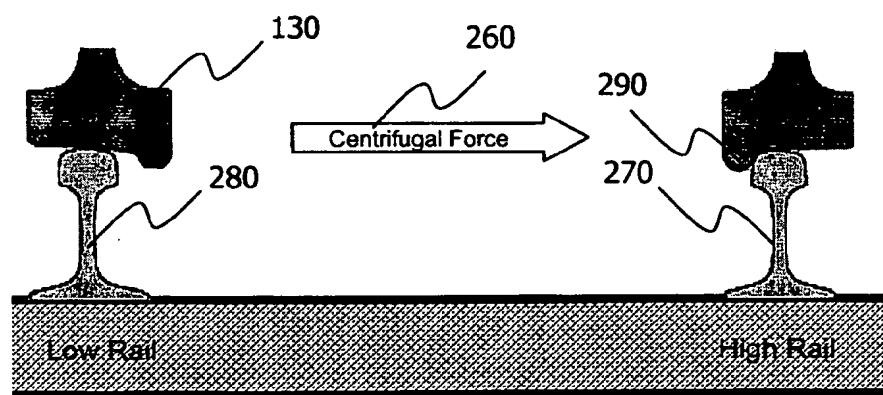


Figure 12B

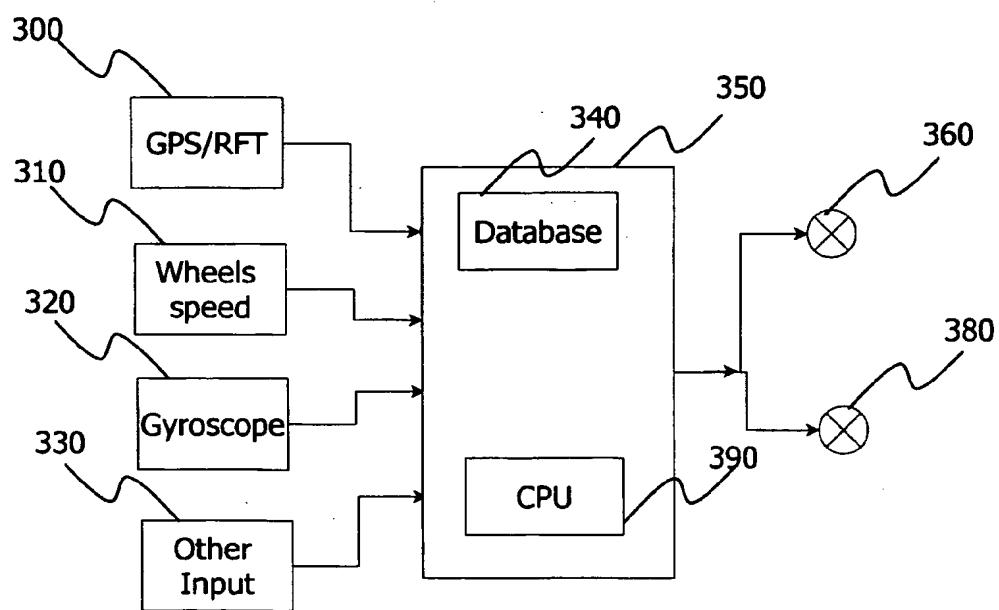


Figure 13

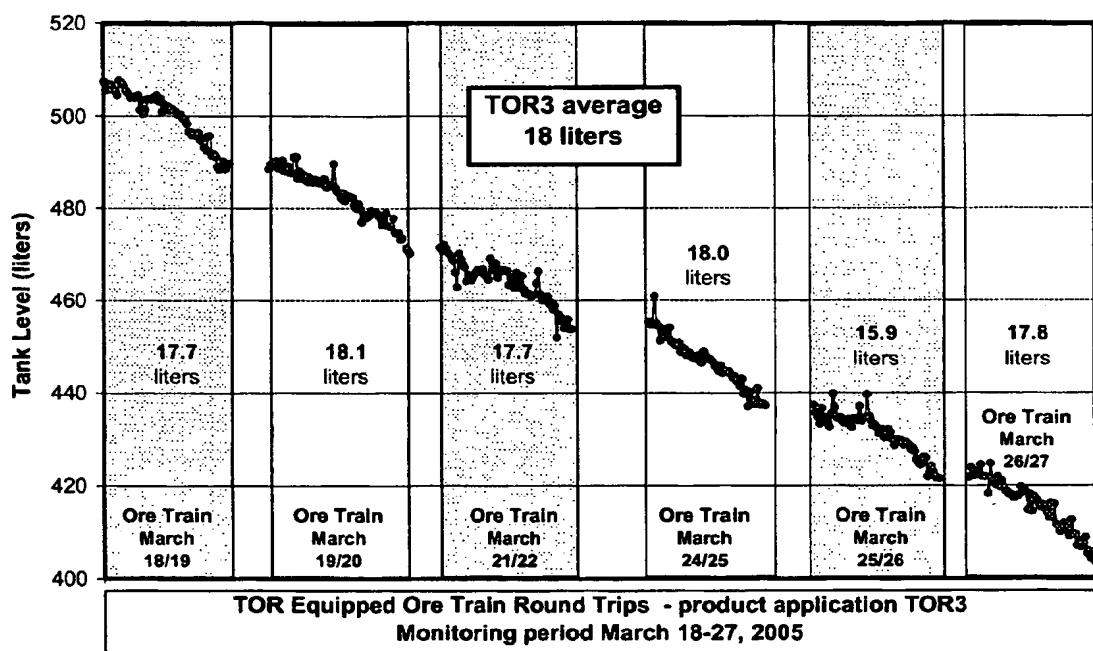


Figure 14

REFERENCES CITED IN THE DESCRIPTION

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